RESILIENCE OR TIPPING POINT?

What can we infer from two decades of stream monitoring data from Pine Ridge Reservation streams?

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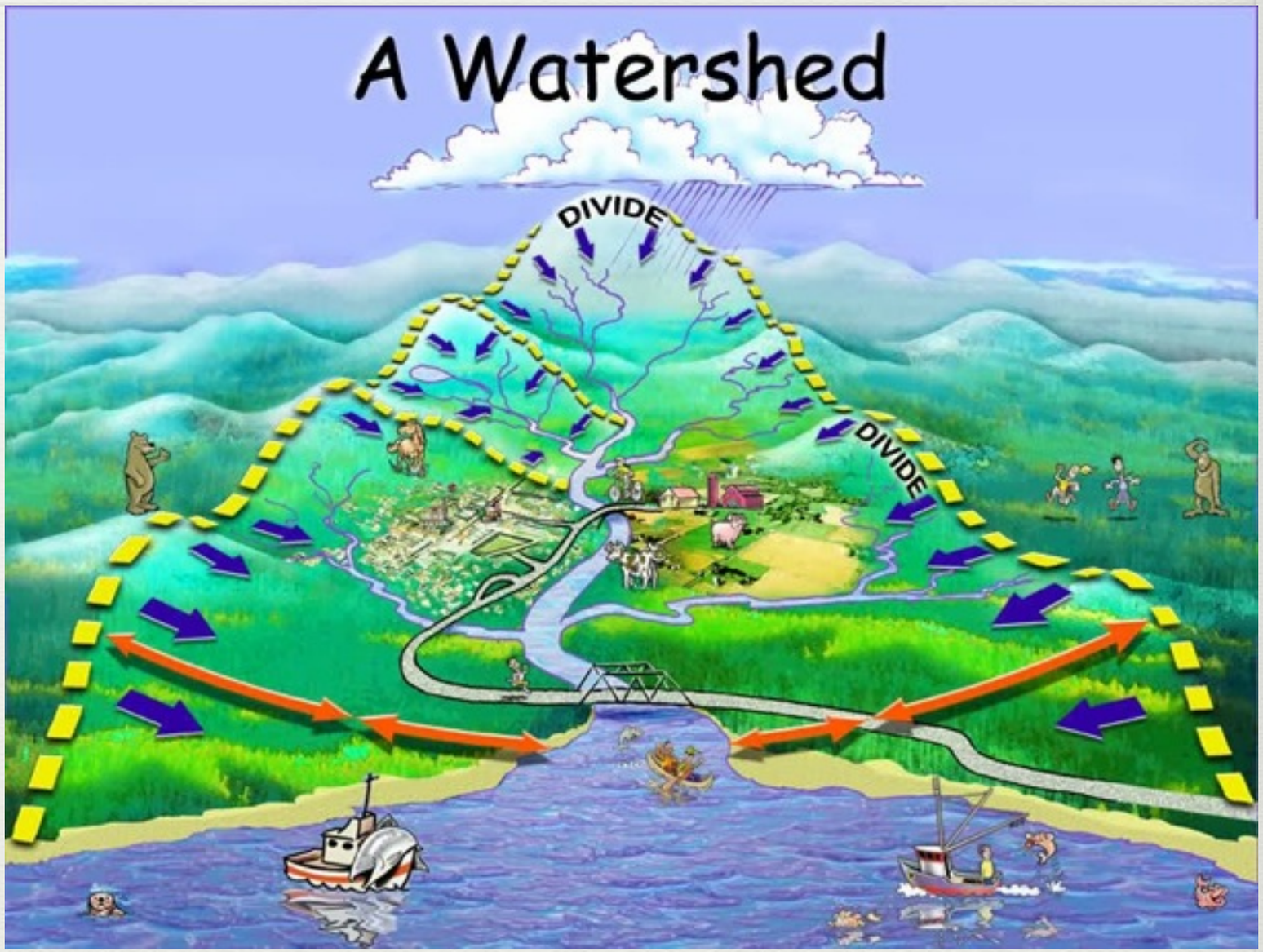
If you think I see further it is by standing on the shoulders of giants* (however if you think I am a fool, then it is my own responsibility)

- Kara Painter & Mike Beasley (WICA) - Fire Ecology 101, 201 etc.
- Maribeth Price (SDSMT) /Dan Roddy & Marie Curtin (WICA) - Spatial Ecology/Weed Science (and a place to play)
- Tom Fontaine (SDSMT) - Statistical Hydrology (and mazaska)
- Jim Weigand (CA BLM) - Desert Ecology (and a place to play)
- Chris McCreedy (PRBO) - Bird Ecology
- Pat (Bat) Brown - Bat Ecology
- Amy Symstad (USGS) - Botany of the Great Plains (and a place to play)
- Scott Kenner and Lisa Kunza (SDSMT) - Stream Health (and significant equipment loans)
- Peter Nelson and Mary Zimmerman (Black Hills) - Lichens and Briophytes
- Charlie White Buffalo, Corey Yellow Boy, Wilmur Mesteth, Dawn (Tobacco) Frank, Dennis Yellow Thunder (OLC/OST)- Mitakuye Oyasin (we are all related)

* Isaac Newton, most famous attribution

Why should a talk about stream monitoring matter to forest and grasslands managers?

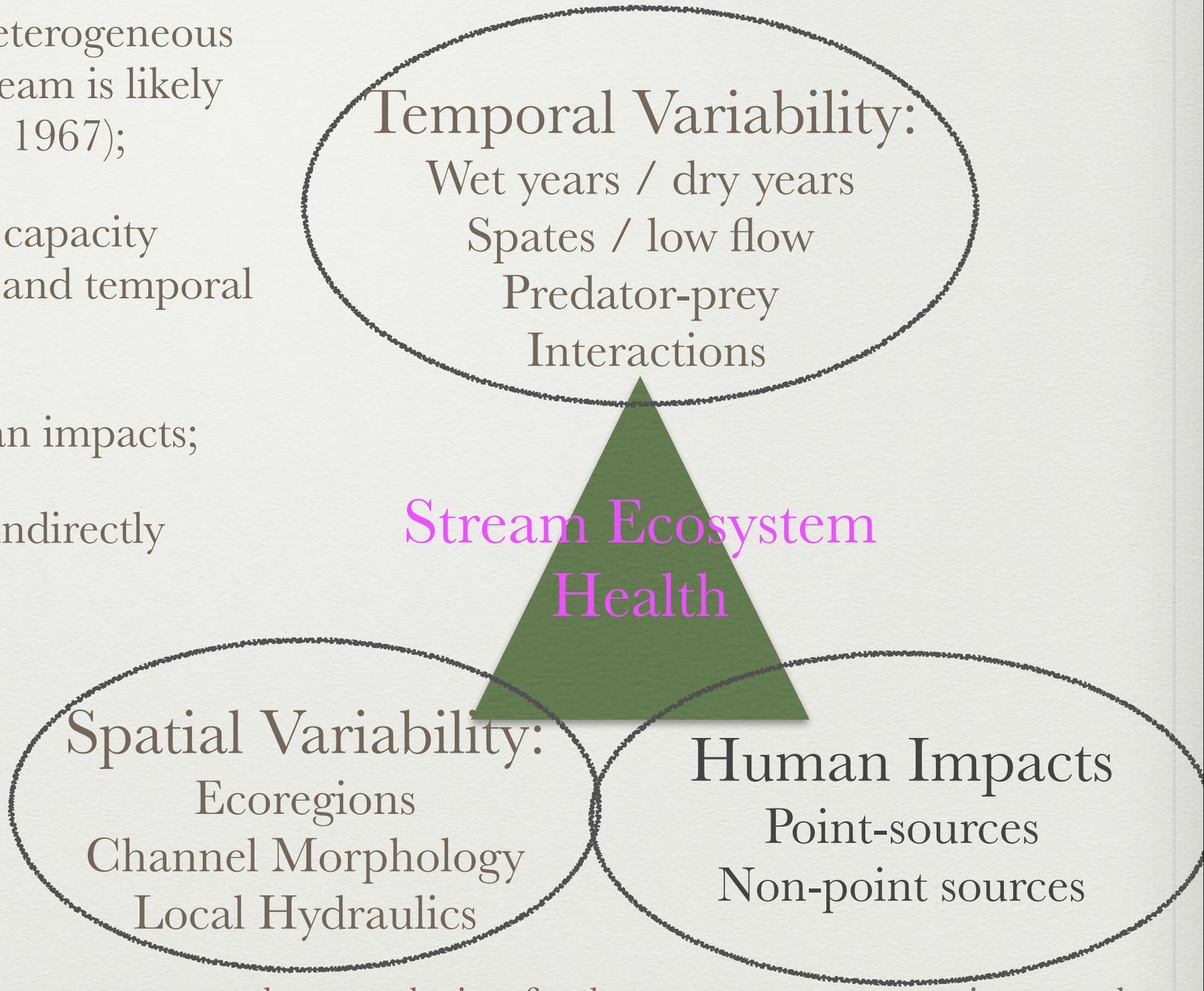
- The stream integrates watershed impacts
- An unhealthy stream is an indicator of a watershed that is out of balance



Oh, College; http://kaceann.wikidot.com/watershed

Why studying stream ecosystems is not rocket science… it's actually much harder*

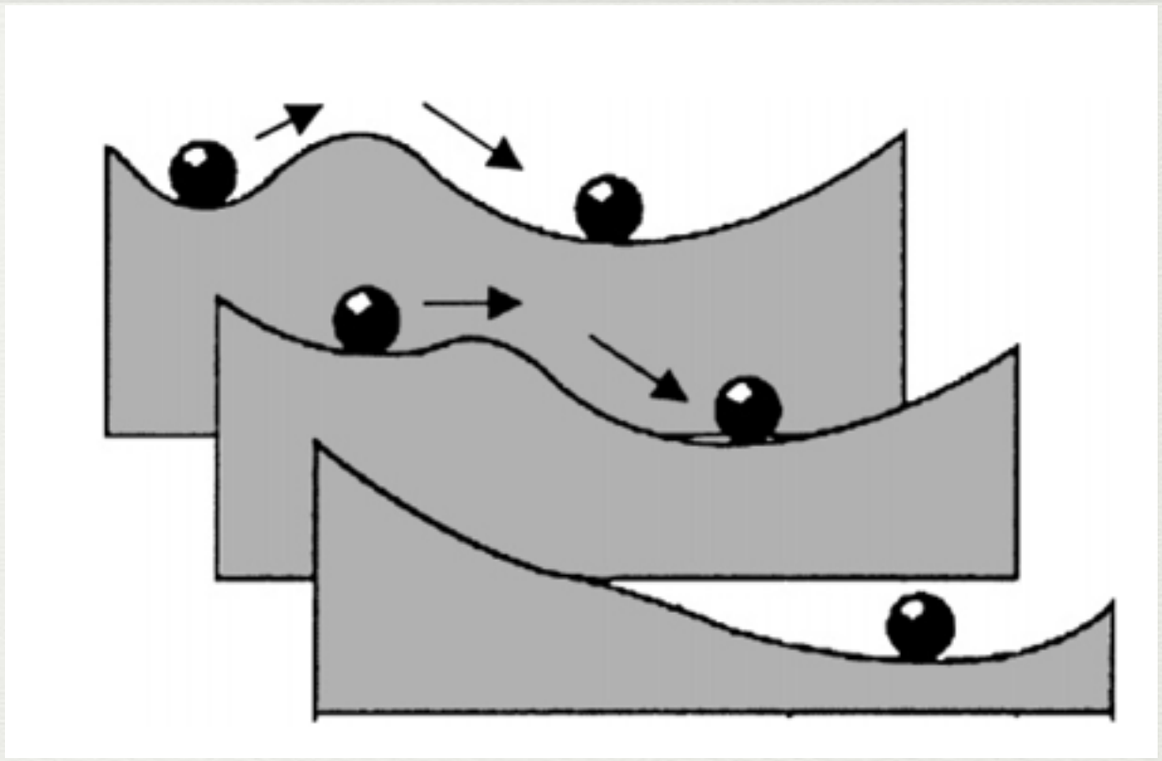
- Streams are dynamic and heterogeneous at multiple scales - "each stream is likely to be unique" (HBN Hynes, 1967);
- The concept of assimilative capacity integrates watershed spatial and temporal variability;
- Multiple unquantified human impacts;
- Stream ecosystem health is indirectly measured (at best!)



* With thanks from Dr. Camaron Barrows - a great desert ecologist - for the quote on ecosystems in general.

Ecosystem Resilience and Tipping Points

Physical Resilience

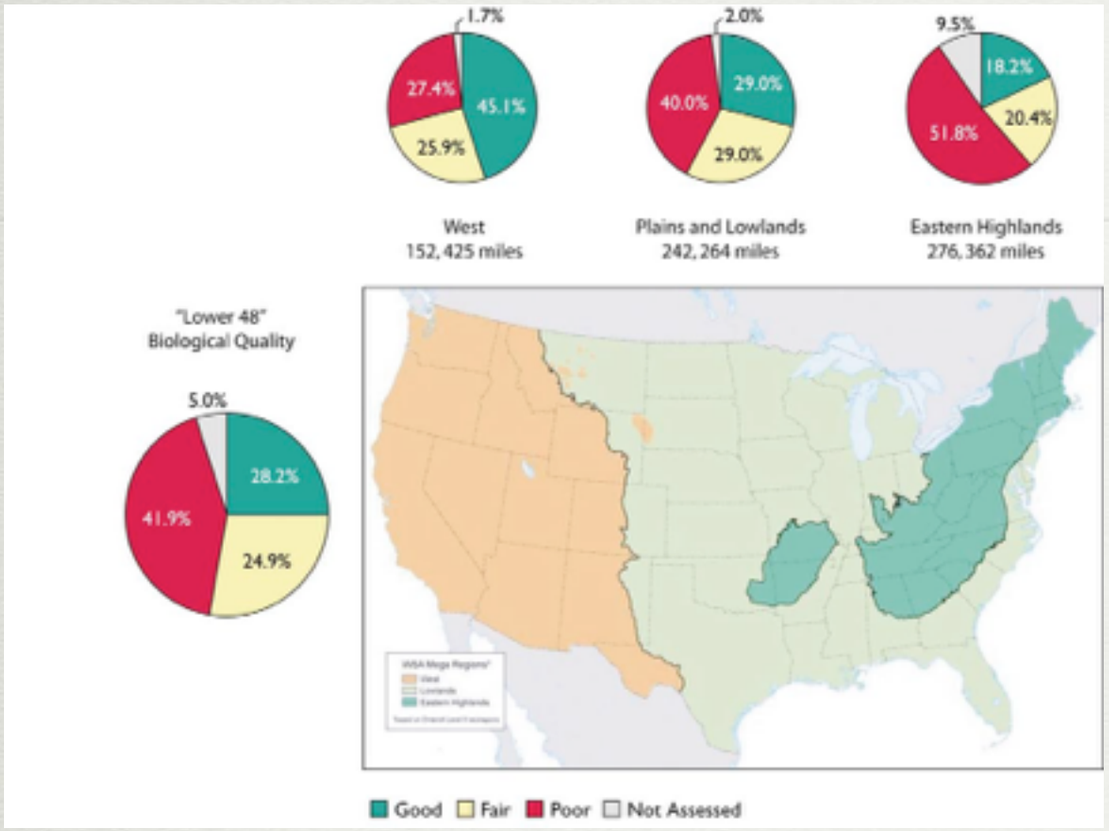


Biological Resilience

- Disturbance types (pushes on the ball) include:
  - Pulses (instantaneous) - floods, fires
  - Presses (increasing over time) - droughts, anthropogenic loadings

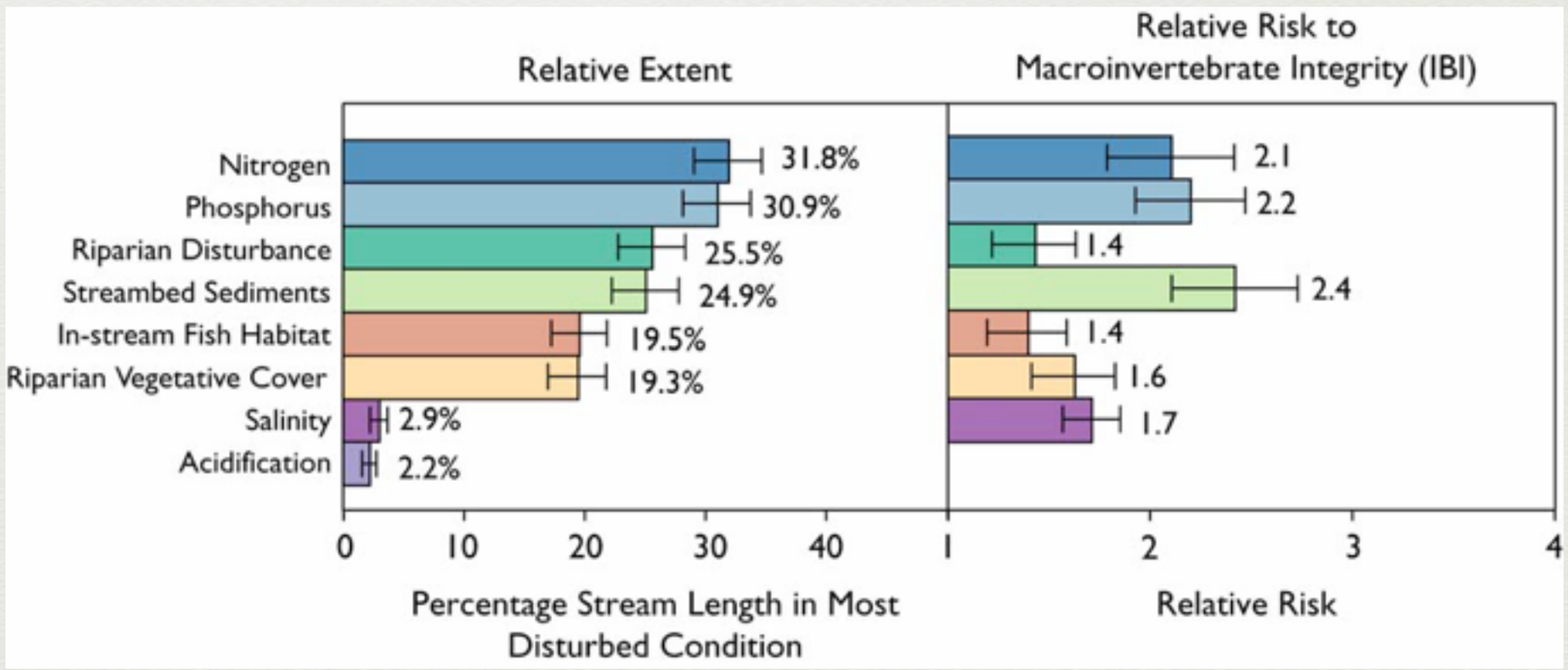
Consider that biological communities exist within a stable state - crossing an ecological threshold causes the community to move to a new (degraded) stable state. Ecological restoration entails pushing the ball back up the hill… (And it might just not work - see Sisyphus)

Watershed Protection is a National Challenge



Anthropogenic Stressors are impacting the Nation's Waters

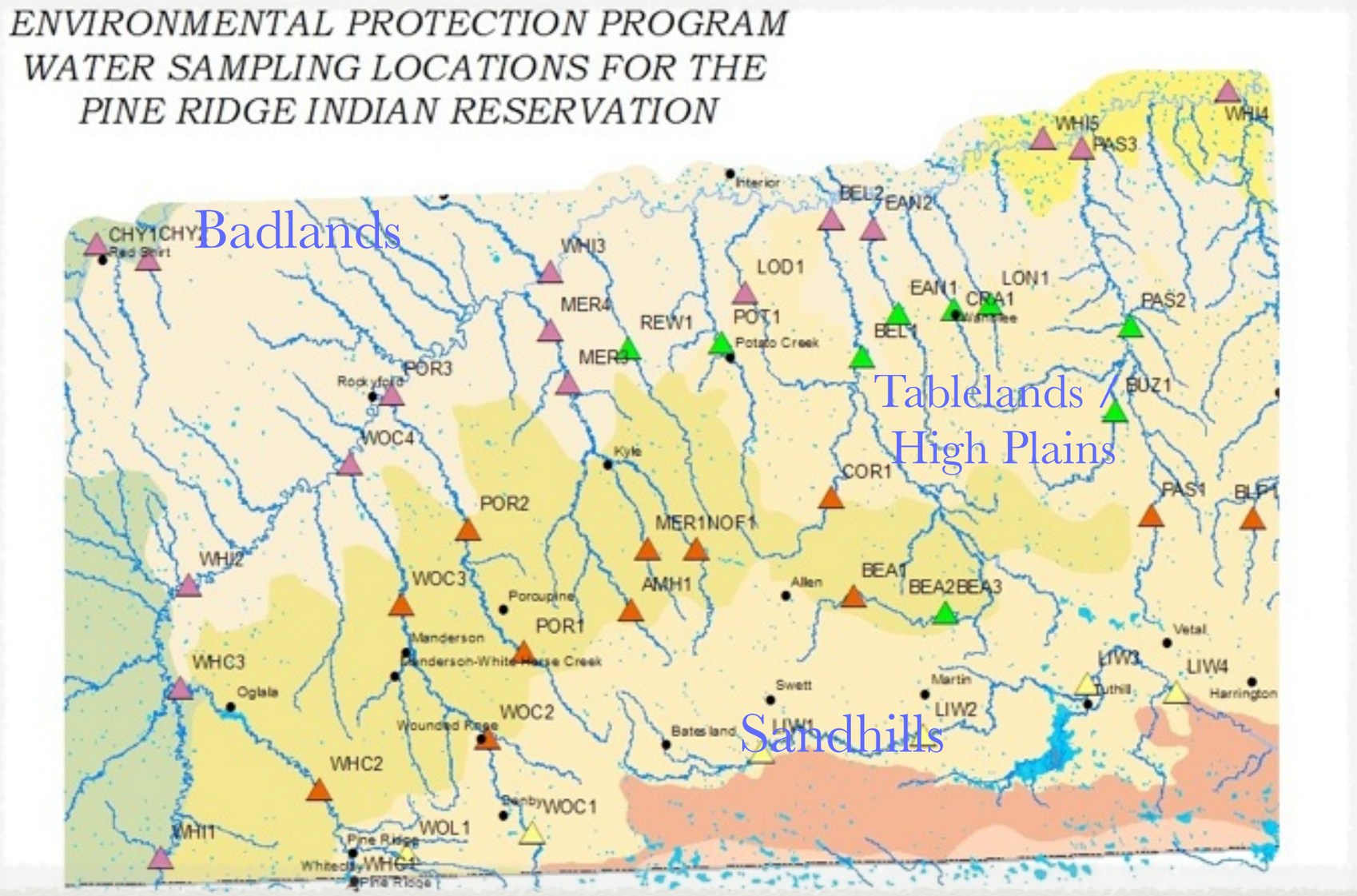
2006 EPA Wadable Stream Assessment



Study Area on the Pine Ridge Reservation in South-central South Dakota from 1993-1996 and 2008-2011

- Alluvial valleys with increasing cohesiveness downstream (north)
  - Sandhills
  - Tablelands/High Plains
  - Badlands
- Low gradient dune-ripple channel morphology
- LWD density depends on riparian area
- Highly buffered waters
- Oligotrophic N-limited
- Grazing is the major land use on the reservation

At present 85% of stream segments are exceeding bacteria standards for WQ*



* Numeric standards for nutrients have not been established for SD

How to assess stream health using macroinvertebrates?

Answer: recruit great student interns…

Stream Macroinvertebrate Metrics Analyzed using MANOVA* to Assess Potential Land Use Change

	Ecoregion	"Land Use"**	Time	Interactions
Taxa Richness	Total number of families			
% EPT	Percentage of intolerant insects (mayflies, stone flies, caddis flies)			
EPT Index	Number of EPT families			
Family Biotic Index	Population weighted index of tolerance			
% Dominance	Percentage of most numerous taxon in an ecological community			
% Diptera and Non insect	Percentage of taxa with adaptations for lower dissolved oxygen			
% Collector Gatherer	Percentage of taxa using feeding strategies associated with increased fin			

* Meets linearity and homoscedasticity assumptions;
** Estimated from life history of dominant macroinvertebrate taxon

	Ecoregion p<0.001 h2=0.191	**"Land Use" p<0.001 h2=0.534**	Time p<0.103 h2=0.138	**Land use x Ecoregion p<0.004 h2=0.127**
Taxa Richness				
% EPT	p<0.001 h2=0.295			p=0.006 h2=0.191
EPT Index		p=0.005 h2=0.120		
Family Biotic Index		p<0.001 h2=0.629	p=0.006 h2=0.074	
% Dominance				
% Diptera and Non insect	p=0.039 h2=0.112	p<0.001 h2=0.378		
% Collector Gatherer	p=0.014 h2=0.137	p<0.001 h2=0.610	p=0.019 h2=0.102	p=0.109 h2=0.162

Bold Header is significant overall (Pillai's Trace), p-values and effect size are for univariate ANOVA as follow-up tests (>95% confidence reported)

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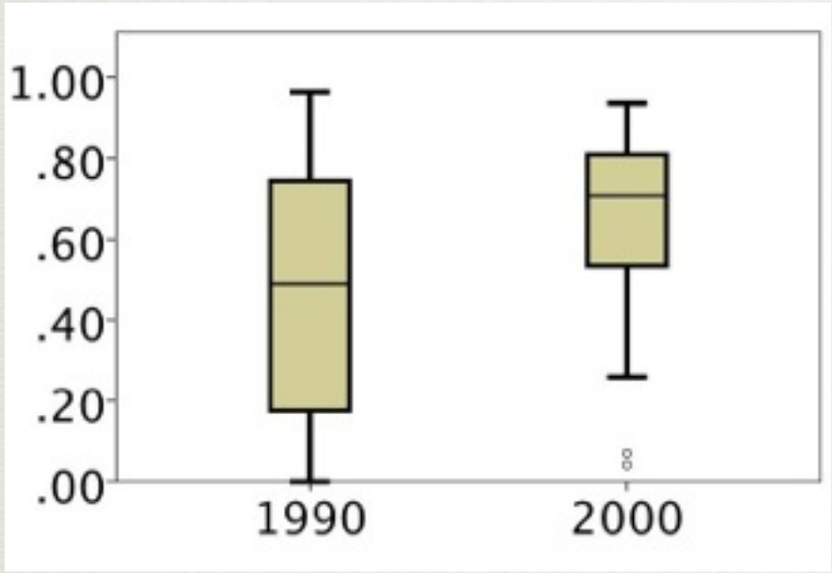
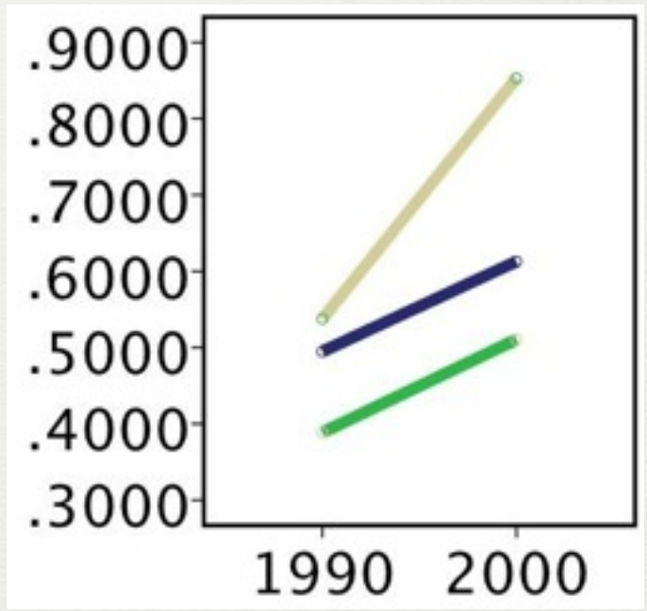
Decreases in Trophic Complexity and Increases in Pollution Tolerance between 1990 and 2011

Box Plots



Estimated Marginal Means

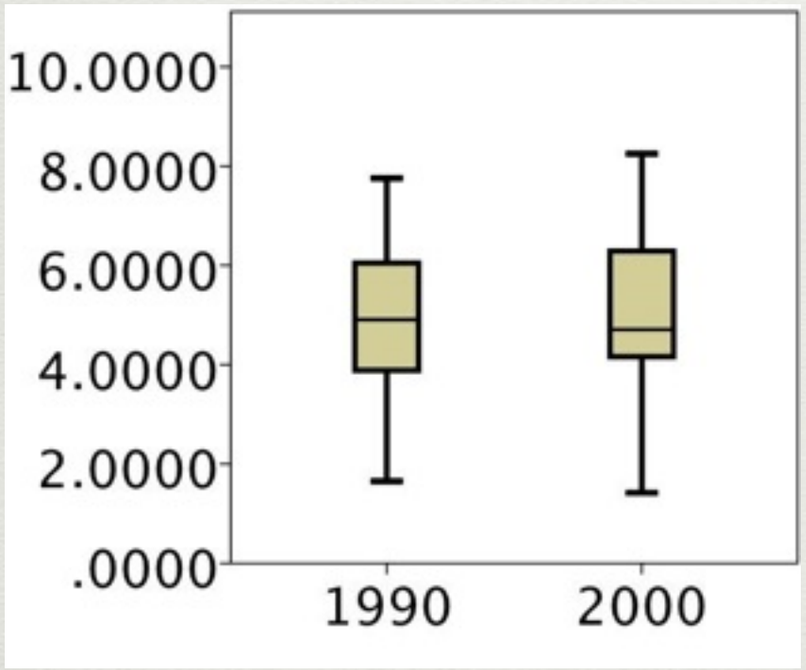


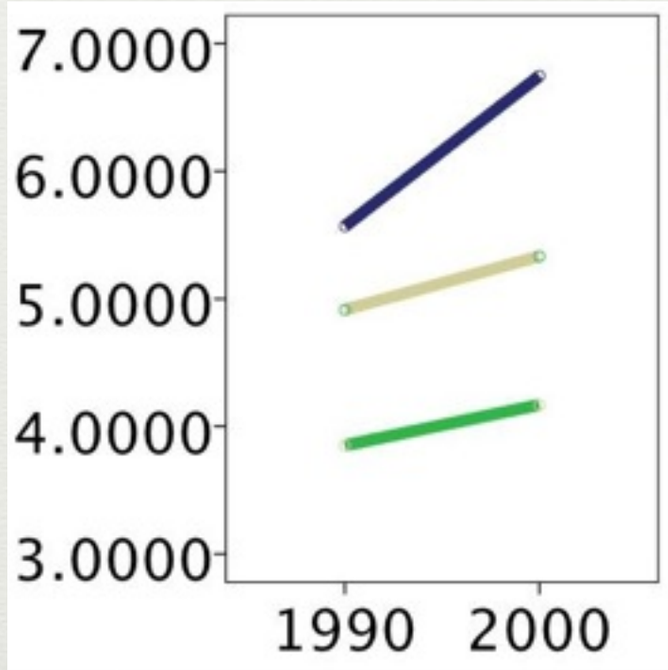
% Collector Gatherer Scores

High Use

Moderate Use

Low Use





Family Biotic Index Scores

High Use

Moderate Use

Low Use

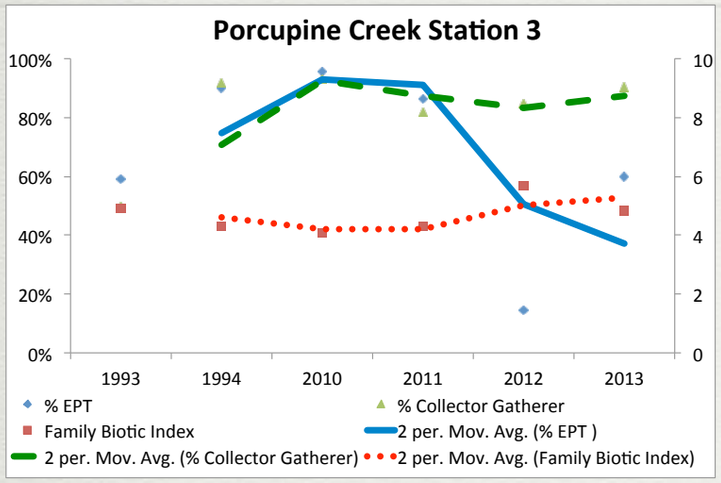
EPT is decreasing and %Collector Gather and FBI scores are increasing since the 1990s

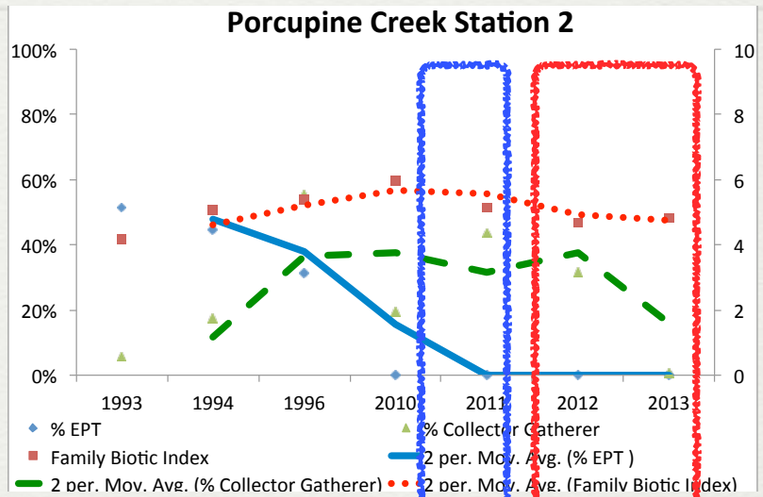
Badlands

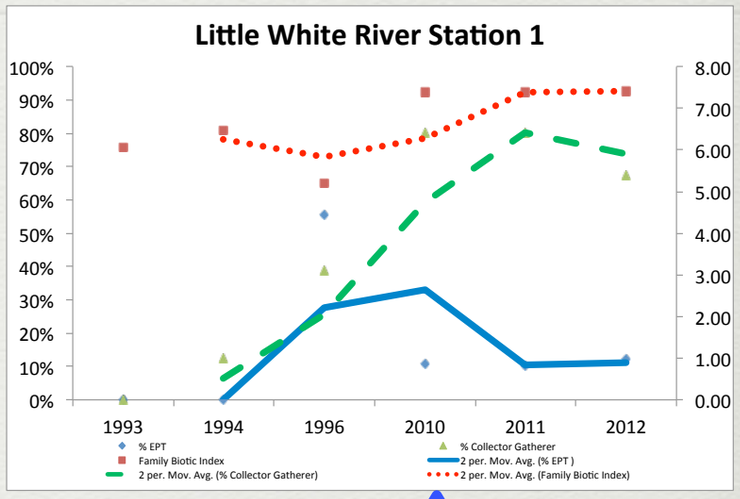
Tablelands

Sandhills

High

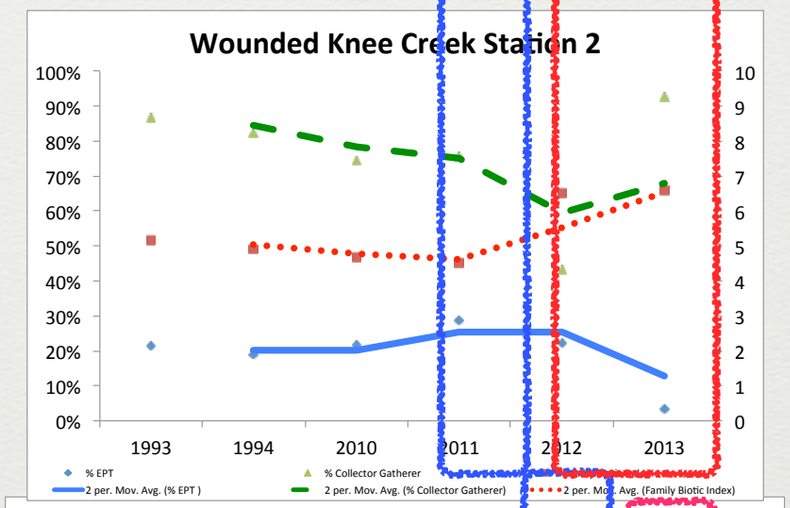






Flood

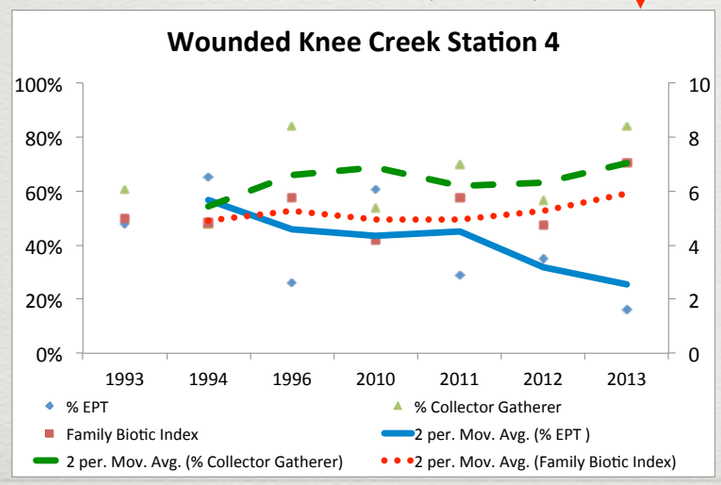
Drought

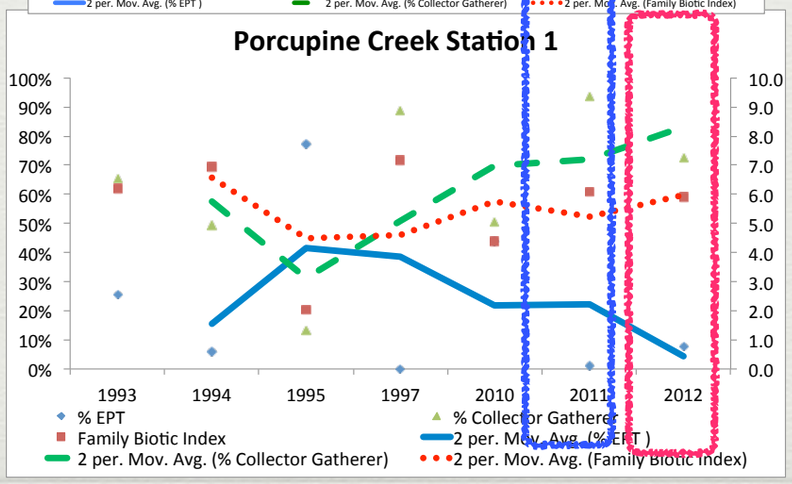


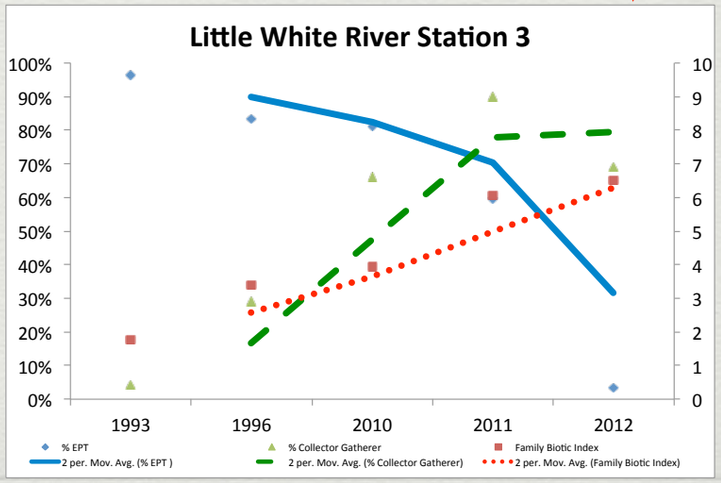
Flood

Drought

Low







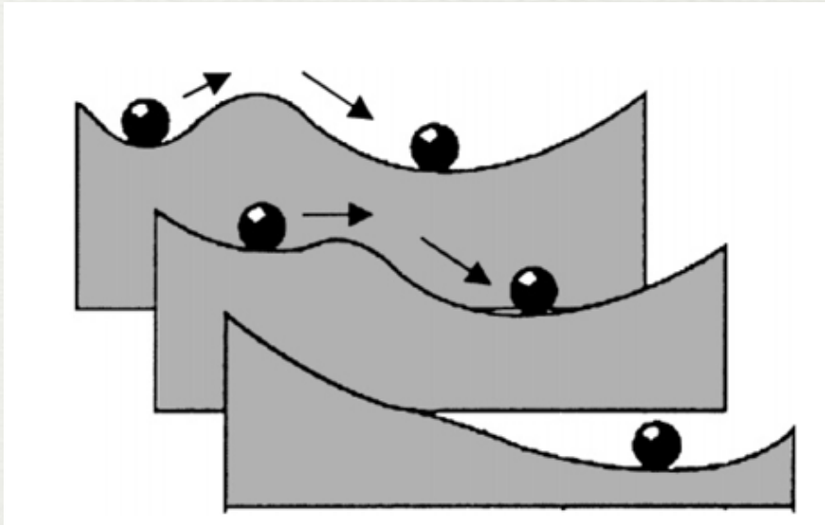
Increases in Total Abundance and Community Changes Indicating Increases in Organic Matter Loading from 1993-96, 2008-11, 2012-13

	Badlands	Tablelands	Sandhills
High	WOK4 Elmidae (n=390) Brachy/Chiron (n=235) Chiron./Oligoch. (n=1350)	POR2 Perlidae/Hydram. (n=280) Elmidae (n=2,600) Chiron./Baetidae (n=3,500)	LWR1 Simul./Hydropsy. (n=1,150) Culcidae/Taltridae (n=2,500) Chironomidae (n=3,500)
	WOK2 Elmidae (n=unknown) Elmidae (n=2,400) Chironomidae (n=10,300)		
Low	POR3 Baetidae (n=610) Baetidae (n=110) Chiron./Baetidae (n=150)	POR1 Chiron./Brachy (n=140) Chiron./Brachy (n=1,900) Chironomidae (n=1,400)	LWR3 Brachycentridae (n=1,150) Polymitreyidae (n=1,250) Caenidae/Elmidae (n=900)

Are the ecosystem changes we are observing related to climate variability or to land use? More importantly, what are the potential feedbacks?

- Macroinvertebrate total abundance increases and community changes are indicative of oligotrophic to eutrophic changes
- Macroinvertebrate community changes are correlated with widespread mesotrophic conditions
- Widespread algal blooms (2012-13) are a response to changes in ecosystem function?
- Are algal blooms driving a community change that will lead to decreased nutrient cycling and more algal blooms?
- If there is a feedback loop, how do we break it?

Reduced buffer between watershed and stream



Increasing hydrologic variability

Loss of nutrient cycling functions

- Consider "the stream and its valley" - stream ecology is intimately linked with watershed physiology and land use practices

So, where do we go from here?

- Slice and dice the data in other ways - NMS and FFG ratios to estimate ecosystem attributes

- Best Management Practices (BMP) applications coupled with continued monitoring (macroinvertebrates + DO + ChlA + Alk + N + P)

Taiya Inlet Watershed Council webpage
http://taiya.org/wp-content/uploads/2013/08/ripvege.jpg

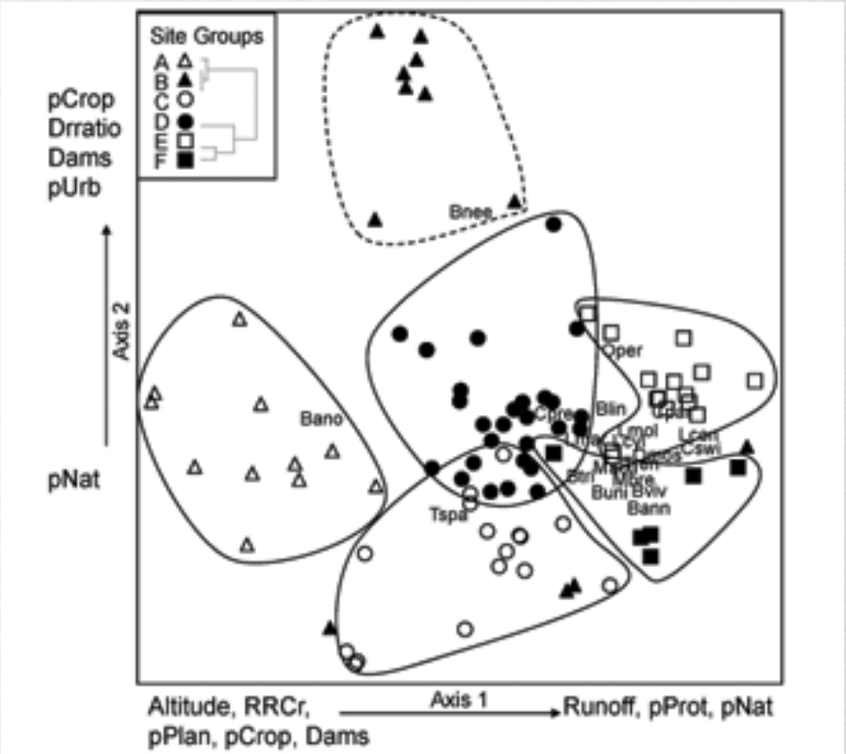


Figure 3
NMS ordination of 87 sites from the Olifants River catchment, based on their fish assemblage data. Symbols represent sites, and they are coded by cluster (cluster analysis dendrogram is shown in inset). Species that were significant indicators for a particular cluster are graphed based on weighted averaging (see Table 2 for species codes). Axis 1 explains 33 % of the variance and Axis 2 explains 31 % of the variance in this system. Environmental variables significantly related to these axes are also shown in this figure (see Table 1).

Brenda Rashleigh, Devlyn Hardwick, Dirk Roux (2009) Water SA (Online) vol.35 no. 4 Pretoria July 2009. http://www.scielo.org.za/scielo.php?pid=S1816-79502009000400017&script=sci_arttext

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